The Factor Structure of the Figural Torrance Tests of Creative Thinking: A Meta-Confirmatory Factor Analysis

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Abstract

To investigate the factor structure of the Figural Torrance Tests of Creative Thinking (Figural TTCT), a meta-confirmatory factor analysis was performed. A sample of 33 correlation matrices from 26 studies ($N_{individuals}$ = 6,982) was included in the meta-analysis. Four different factor models previously presented in the literature were tested to determine which model fits the data best. The results supported a two-factor structure model in which fluency and originality subscales loaded on the innovative factor, while elaboration, abstractness of titles, and resistance to premature closure subscales loaded on the adaptive factor. Implications, limitations, and suggestions for future research are discussed.

Keywords: creativity, Figural Torrance Tests of Creative Thinking, construct validity, factor structure, meta-confirmatory factor analysis

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Creativity is increasingly considered as a key element for achieving sustainable development. The rapidly changing world around us forces individuals, organizations, and societies to seek creative ideas in order to cope and keep competitive (James, Clark, & Cropanzano, 1999; Lubart, Zenasni, & Barbot, 2013). Hence, creativity has received a great deal of attention in different strands of research, including psychology and the educational sciences. Despite this, the exact nature of creativity is still elusive (Barbot, Besançon, & Lubart, 2015). This could be attributed to the challenge of constructing and applying valid instruments for its measurement (Kaufman, Baer, Cole, & Sexton, 2008; Mouchiroud & Lubart, 2001; Said-Metwaly, Kyndt, & Van den Noortgate, 2017b). In this regard, numerous instruments for the measurement of creativity have been developed. They look at different aspects of this construct, including creative processes, creative products, personality traits of creative individuals, or the climate where creativity occurs (Barbot, Besançon, & Lubart, 2011; Fishkin & Johnson, 1998; Kaufman & Baer, 2002; Plucker & Renzulli, 1999; Rhodes, 1961).

For many decades, instruments measuring creative processes have been extensively employed in creativity research; among them, divergent thinking instruments remain the main measure of such processes (Benedek, Mühlmann, Jauk, & Neubauer, 2013; Plucker & Renzulli, 1999; Zeng, Proctor, & Salvendy, 2011). Divergent thinking instruments are also known as ideational fluency measures because they assess an individual’s ability to generate several responses to open-ended problems (Plucker, Qian, & Wang, 2011; Plucker & Renzulli, 1999). The Torrance Tests of Creative Thinking (TTCT) is probably the most widely used among the divergent thinking instruments for measuring creative potential (Baer, 2015; Plucker et al., 2011). The TTCT has been translated into over 35 languages (Kapoula & Vernet, 2016; Millar, 2002) and has been used in more than 2,000 published research studies (Torrance, 2000). It was first published by Paul Torrance and his colleagues in 1966 and then renormed in 1974, 1984, 1990, 1998, and 2008 (Kim, 2011). The development of the TTCT is grounded on Guilford's Structure of Intellect model (Davis, 1989; Kaufman, Plucker, & Russell, 2012; Krumm, Lemos, & Filippetti, 2014). It assesses an individual's ability to think creatively in either verbal or nonverbal modes (Clements, 1991). The TTCT battery includes a Verbal test (Thinking Creatively with Words) and a Figural test (Thinking Creatively with Pictures), with two parallel forms (A and B) for each test (Torrance & Haensly, 2003).

The Figural TTCT has undergone over 25 years of extensive validation (Millar, 2002). It can be administered from the age of 5 years upward (Torrance, 2000). It comprises three 10 minutes activities: Picture Construction, Incomplete Figures, and Repeated Figures (Torrance & Haensly, 2003). In the Picture Construction activity, the subject is asked to use the given shape (a kidney or teardrop shape) as a basis to create a picture. The Incomplete Figures activity requires the subject to finish and label incomplete figures. The Repeated Figures activity requires the subject to use the provided circles or lines to develop a meaningful drawing. Responses on these activities are typically scored for fluency (i.e., the number of relevant responses), flexibility (i.e., the number of different categories of responses), originality (i.e., the number of unique responses), and elaboration (i.e., the amount of details in responses) (Cramond, Matthews-Morgan, Bandalos, & Zuo, 2005; Prieto et al., 2006). The newest scoring system of the Figural TTCT provides five norm-referenced measures: fluency, originality, elaboration, resistance to premature closure (i.e., the degree of psychological openness to various information), and abstractness of titles (i.e., the degree beyond labeling of the pictures drawn), in addition to thirteen criterion-referenced measures of creative strengths that assess several creative thinking and personality constructs (e.g., emotional expressiveness, unusual visualization, humor, breaking boundaries, and fantasy) (Kim & Zabelina, 2015; Torrance, 2000).

Despite the prevailing use of the Figural TTCT, there has been considerable debate about its validity (Baer, 2015; Said-Metwaly, Kyndt, & Van den Noortgate, 2017a). A great deal of this debate has centered around the construct validity of this instrument (Clapham, 1998; Zeng et al., 2011). It is not quite clear what or how many creativity dimensions are measured by the Figural TTCT (Zeng et al., 2011). This could be imputed to the limited number of studies that examined the latent structure of the Figural TTCT (Kim, 2006a, 2006b; Kim, Cramond, & Bandalos, 2006), along with the inconsistent results of these studies (Almeida, Prieto, Ferrando, Oliveira, & Ferrándiz, 2008; Krumm, Filippetti, Lemos, Koval, & Balabanian, 2016). Using principal component analysis (PCA), Heausler and Thompson (1988) and Clapham (1998) showed that the subscores of the Figural TTCT reflected one general factor. Other studies found a multidimensional factor structure for the Figural TTCT. Based on exploratory factor analysis (EFA), Plass, Michael, and Michael (1974) revealed seven factors for the Verbal and Figural TTCT. The obtained factors described the demands of each task rather than the hypothesized creativity cognitive processes. Prieto et al. (2006) also analyzed the Figural TTCT data using EFA and found three factors related to the tasks, in addition to a fourth factor related to the elaboration process. Similarly, by means of PCA in three empirical studies conducted in Spain and Portugal, Almeida et al. (2008) showed that the subscales of the Verbal and Figural TTCT were loading on more than one factor (three, five, and six factors) not related to the assessed creativity processes, but to the specific content and demand of each task.

A number of studies using confirmatory factor analysis found support for a two-factor structure of the Figural TTCT adapted from Kirton's (1976, 1984, 2003) Adaption-Innovation Theory (e.g., Kim, 2006b; Kim et al., 2006; Krumm et al., 2016; Krumm, Lemos, & Filippetti, 2014). This theory is grounded on the assumption that all individuals are creative, yet dissimilar in the cognitive style through which they express their creativity (Kirton, 2003). According to this theory, individuals are located on a continuum ranging from high adaptation to high innovation (Kirton, 1976, 2003). Adaptors seek to create change by improving upon the existing paradigms or systems, whereas innovators seek to create change by developing new paradigms (Kirton, 1984). Aiming to "doing things better", adaptors tend to produce few novel, relevant, and acceptable ideas (Kirton, 1984, 2003). Aiming to "doing things differently", innovators tend to produce multiple novel ideas, without considering whether they are relevant or acceptable (Kirton, 1984, 2003). Kim et al. (2006) suggested that adaptation and innovation might be viewed as separate dimensions rather than two opposite ends of a continuum. Further, Krumm, Lemos, and Filippetti (2014) hypothesized that innovative individuals were more likely to generate more rapid and original responses, while adaptive individuals were more likely to generate more profound (in-depth) and detailed responses. In accordance with this hypothesis, trained scorers of the TTCT have characterized two kinds of individuals: those who performed better on fluency and originality subscales, and those who performed better on elaborations and abstractness of titles subscales (Kim et al., 2006). Moreover, it was suggested that resistance to premature closure might bear on either the innovative or adaptive style of creativity (Kim et al., 2006). This arose from Torrance's hypothesis that creative individuals would be capable of maintaining their mind open to new ideas while processing information, whereas less creative individuals would prematurely skip to conclusions (Kim, 2006b; Kim et al., 2006). Following this, two-factor structure models for the Figural TTCT were suggested (see Krumm et al., 2016; Krumm, Lemos, & Filippetti, 2014). Generally, the first latent factor in these two-factor models, labeled innovative, comprises fluency and originality subscales, while the second latent factor, labeled adaptive, comprises elaboration and abstractness of titles subscales. The only difference among these models is the position of the resistance to premature closure subscale in relation to these two factors. Within these models, resistance to premature closure is hypothesized to be a part of either the innovative factor, the adaptive factor, or both.

The Current Study

Despite years of research, considerable debate still exists over the dimensionality of the Figural TTCT. Exploratory and confirmatory approaches employed in studies investigating the factor structure of the Figural TTCT have yielded inconsistent results. Available research thus lacks either theoretical or empirical evidence to draw generalizable conclusions about its structure. Given this, the purpose of this study was to investigate the factor structure of the Figural TTCT. In particular, the study was conducted to explore whether creativity as measured by the Figural TTCT is a unidimensional or two-dimensional construct. Based on previous research (Clapham, 1998; Heausler & Thompson, 1988; Kim, 2006b; Kim et al., 2006; Krumm et al., 2016; Krumm, Lemos, & Filippetti, 2014), four factor structure models for the Figural TTCT were tested (see Figure 1). The first model assumes a one-factor structure (unidimensional), while the three remaining models assume a two-factor structure (two-dimensional). For the first model, all the subscales of the TTCT are loaded on one general creativity factor. For the second model, the latent innovative factor includes fluency, originality, and resistance to premature closure, while the latent adaptive factor includes elaboration and abstractness of titles. For the third model, the innovative factor comprises fluency and originality, while the adaptive factor comprises elaboration and abstractness of titles; both factors comprise resistance to premature closure. For the fourth model, the innovative factor involves fluency and originality, while the adaptive factor involves elaboration, abstractness of titles, and resistance to premature closure.

To evaluate the four suggested models of the TTCT, a meta-confirmatory factor analysis (meta-CFA) approach was used. A meta-CFA is based on pooling inter-item correlation matrices from samples of previous studies, which are then used as input for CFA to test the fit of the factor structure models (Cheung, 2014; Cheung, 2015a). As a result, the meta-CFA might be more advantageous than conventional statistical approaches as it allows the proposed models to be tested across multiple samples, conditions, and measurements (Cheung, 2015a). The meta-CFA is different from other previously used approaches in creativity literature and might bring much-needed clarity to the valid factor structure underlying the Figural TTCT. By conducting the meta-CFA, the present study allows investigating the results of earlier studies and comparing previously identified structure models, therefore reducing conflicts that might have arisen from using different samples or statistical approaches.

Method

The papers included in this study were identified by systematically searching creativity literature published up to February 28, 2017. The search process consisted of the following four steps: First, the following databases were searched: ERIC, Google Scholar, JSTOR, PsycARTICLES, and Web of Science using the following search string: (“creativity” OR “creative thinking” OR “creative performance” OR “creative ability” OR “creative potential”) AND (“Torrance Tests of Creative Thinking” OR “TTCT”). Second, the reference lists of the papers identified in the first step were reviewed for other relevant references (i.e., “backward search”). Third, more recent references were retrieved through searching databases for papers that referred to the previously identified papers in steps 1 and 2 in their citations (i.e., “forward search”). Fourth, the following key journals in creativity were hand-searched: *Creativity Research Journal*, *Gifted Child Quarterly*, *Psychology of Aesthetics, Creativity, and the Arts*, *The Journal of creative Behavior*, and *Thinking Skills and Creativity*.

The papers identified using this search process were selected if they used the Figural TTCT (form A or B) and included a zero-order correlation matrix among the dimensions of this instrument (papers that only included partial correlations or path coefficients were not included). Studies that only reported a part of the correlation matrix of interest were also included in our analysis. When a study reported analyses on more than one subgroup sample (e.g., analyses by gender, age, or class), these subgroup samples were considered as independent and their correlation matrices were included, but the correlation matrix for the whole sample was excluded. For studies that reported multiple measurements for the same sample (e.g., repeated measures analysis), we only included the correlation matrix from the first measurement.

Procedures for Meta-CFA

Using the method suggested by Cheung and Chan (2005), a two-stage approach was used to perform the meta-CFA. In the first stage, the correlation matrices from different studies are tested for homogeneity. If homogeneity is found, correlation matrices are combined to produce a pooled correlation matrix. If between-study heterogeneity is found, a random-effects model is applied in order to take into account that the population correlation matrix may differ across studies. When a random-effects model is applied, a pooled correlation matrix is also estimated but this matrix does not represents the estimate of a unique population correlation matrix any more, but the estimate of the average of the population matrices. By applying a random-effects models, the variability across studies can be estimated (between-study variability) and thus taken into account for the second stage. In the second stage, the pooled matrix is considered as the observed matrix and is employed for the CFA (Cheung, 2014). At these two stages, fit indices were used to ensure that the required assumptions were met. As fit indices, chi-square (χ^2), normed chi-square (χ^2/df), incremental close-fit, i.e., the comparative fit index (CFI), and absolute close-fit, i.e., the root mean square error of approximation (RMSEA), and the standardized root mean square residual (SRMR), indices were reported. Smaller and insignificant χ^2 values represent a good fit (Barrett, 2007; Hooper, Coughlan, & Mullen, 2008). The acceptable range for χ^2/df is between 1 and 5 (Schumacker & Lomax, 2004). Absolute close-fit values smaller than .06 and CFI values greater than or equal to .95 were considered as an acceptable fit (Hooper et al., 2008; Hu & Bentler, 1999). For the first stage, a diagonal matrix was used to estimate the between-study variance, assuming that the random effects are independent. I^2 statistic was used to estimate the percentage of variability across the included studies belonging to heterogeneity rather than chance (Higgins & Thompson, 2002). For the second stage, Likelihood-based confidence intervals for the loadings were asked, as they are preferred over the confidence intervals based on the standard errors (Cheung, 2009).The analysis was carried out using the package *metaSEM* (Cheung, 2015b) for software *R* version *3.3.3*.

Results

Papers Meeting the Inclusion Criteria

After 2641 papers were screened, 26 papers were selected. Some of these papers included multiple correlation matrices for independent samples. This yielded a primary sample of 39 correlation matrices. Six of these correlation matrices were excluded as they were obtained from multiple analyses with the same sample. Thus, the final sample used in the meta-analysis was made up of correlation matrices from 33 independent samples, including 6,982 subjects in total. Selected papers are listed in Table 1, and papers with multiple independent samples are indicated by an asterisk (*). Twenty five (75.76%) of the matrices were obtained from papers published between 2003 and 2017. Moreover, 28 (84.85%) of the correlation matrices were derived from published studies, and only 5 (15.15%) of the matrices were derived from conference papers and dissertations. In addition, 21 (63.64%) of the correlation matrices were obtained from studies conducted in the USA. Finally, 28 (84.85%) of the matrices were generated through student samples.

Homogeneity of the Correlation Matrices

Fit indices for the homogeneity of the correlation matrices were: χ^2 (204) = 2897.62, p < .001, χ^2/df = 14.20, CFI = .81, RMSEA = .25, and SRMR = .16. Table 2 provides estimates of the I^2 index for the percentage of variability across studies. Except for the correlation between abstractness of titles and resistance to premature closure, I^2 indicated large heterogeneity for the correlations between the Figural TTCT subscales across studies and ranged from 82% to 99%. These indices indicate that the correlation matrices cannot be considered homogenous, that is, we cannot assume that the sample correlation matrices include estimates of a common population matrix. As a result, a random-effects model was employed in the CFA.

CFA model fits

For each factor model, results regarding fit indices and standardized loadings on the hypothesized factors were obtained and judged for statistical significance. Fit indices for the four models are reported in Table 3. Standardized factor loadings for each model are shown in Figure 2. With regard to the first model, the unidimensional model, the factors loadings were all acceptable, varying from .55 to .70. However, the fit indices (except CFI and RMSEA) for this model were unsatisfactory. In fact, the fit of the first model was the worst among the four tested models. Following the same trend as the first model, the second model did not fit the data well, although yielding adequate factor loadings ranging between .61 to .72. In the case of the third model, a considerable improvement in all fit indices was achieved compared to the two previous models. Except for the loading of resistance to premature closure on the innovative factor (.09), all the loadings were acceptable and ranged from .59 to .83. The low loading of resistance to premature closure on the innovative factor indicates that this subscale functions differently than the other subscales related to this factor. Finally, the fourth model showed the best fit among the four models investigated, as well as positive and acceptably high factor loadings ranging from .57 to .84. These results suggest that the fourth model explains the creativity construct best.

Discussion

This study aimed to investigate the factor structure of the Figural TTCT by means of meta-CFA. In general, the results of this study revealed that the two-factor structure models demonstrated a better fit than the one-factor structure model. This suggests that the creativity measured by the Figural TTCT should not be conceived as a unidimensional construct. This result supports the results of studies that used CFA (e.g., Kim, 2006b; Kim et al., 2006; Krumm et al., 2016; Krumm, Lemos, & Filippetti, 2014) and contradicts the results of studies that used PCA (e.g., Clapham, 1998; Heausler & Thompson, 1988). The two-factor model that had the best fit (i.e. the fourth model) included the innovative factor loaded by fluency and originality and the adaptive factor loaded by elaboration, abstractness of titles, and resistance to premature closure. This is in line with Kirton’s Adaption-Innovation Theory and with the results of two previous studies (Krumm et al., 2016; Krumm, Lemos, & Filippetti, 2014). At first glance, this result might seem inconsistent with Kim (2006b) and Kim et al. (2006), who supported the structure model in which the innovative and the adaptive factors were both loaded by resistance to premature closure (i.e. the third model in our study). However, these two studies compared only two of the four models included in the current study, that is, the first and the third model. In agreement with the results of these two studies, our results indicated that the third model provided a better fit than the first model, but the fourth model showed a superior fit compared to all other models.

This study adds to the growing literature on creativity measurement in several ways. First, the results of this study inform the ongoing debate on the factor structure of the TTCT. Second, this study provides a look at the factor structure of the TTCT using meta-CFA, in which the use of data from multiple studies is expected to increase the precision of the estimates and the power of the significance tests. Third, the findings provide valuable insight into the size of heterogeneity in the correlations between the Figural TTCT subscales across the previous studies. Finally, this study has significant implications for the users of the TTCT such as researchers, educators, and gifted-talented programs. Based on the results of this study and Kim's (2006b) suggestion, the Figural TTCT could provide information not only about individuals' creativity level, but also about their creativity style (innovative or adaptive).

This study also has a number of limitations. First, like any meta-analysis, this study is confined by the limitations of the primary studies that were included. For instance, limitations related to sampling or testing conditions in the primary studies might distort our conclusions. Second, our analysis only included the total score of each of the TTCT subscales because the correlation matrices for the test's activities were not made available to us. Third, comparing the factor structure of the two forms of the Figural TTCT, A and B, was not possible because many studies in our meta-analysis did not specify which form was used. Fourth, the creative strengths subscale could not be included due to the very few studies using this subscale (only Kim's (2006b) study). Finally, there were insufficient studies available to compare the factor structure of the Figural TTCT across gender, grade level, or culture. Taking these limitations into account, further studies including additional forms or subscales of the TTCT will need to be undertaken. Moreover, the factor structure of the TTCT should be examined on different variables (e.g., gender, grade level, or culture) in order to obtain more information about how these variables affect this factor structure. Also, this study might be repeated using other divergent thinking instruments to verify factor structures obtained by exploratory or confirmatory analyses. Furthermore, studies using other statistical analyses such as item response theory would help to validate the results of the present study. Still, the results of this study provide important information regarding the factor structure of the creativity construct measured by the Figural TTCT and suggest that the meta-CFA might offer a valuable approach to further clarify this issue.

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Table 1

Papers Included in the Meta-Analysis

Author	Year	Publisher	Country	*N*	No. of matrices	Gender (Male%)	Grade	Age range *(M/SD)*
*Gezi	1969	Conference	USA	67	2	43.28	5th-6th	11-12
Aliotti, Britt, & Haskins	1975	Journal	USA	94	1	45.74	High school	14-19 (16.25/-)
Goolsby & Helwig	1975	Journal	USA	79	1	-	5th	-
Lowery	1982	Journal	USA	36	1	-	3th-5th	-
Fitzgerald & Hattie	1983	Journal	Australia	103	1	51.45	Secondary	16-19 (17.12/0.90)
Clements	1991	Journal	USA	73	1	45.20	3th	8-9 (8.67/0.41)
Han, Marvin, & Walden	2003	Journal	USA	45	1	53.33	Kindergarten	4-6
Cockcroft & Hartgill	2004	Journal	South Africa	36	1	72.22	4th-7th	10-13
Kim	2006b	Journal	USA	500	1	48.40	6th	10-12
*Kim et al.	2006	Journal	USA	3000	3	48.63	Kindergarten-6th	5-13
*Roskos-Ewoldsen, Black, & Mccown	2008	Journal	USA	70	2	-	-	18-86
Hamlen	2009	Journal	USA	118	1	-	4th-5th	-
Houtz & Selby	2009	Journal	USA	41	1	31.70	Undergraduate and graduate	18-35 (23.57/3.66)

Table 1 (continued)

Author	Year	Publisher	Country	*N*	No. of matrices	Gender (Male%)	Grade	Age range *(M/SD)*
*Barkul & Potur	2010	Journal	Turkey	746	2	37.89	Undergraduate	-
Runco, Millar, Acar, & Cramond	2010	Journal	USA	60	1	46.67	-	56
Fink, Slamar-Halbedl, Unterrainer, & Weiss	2012	Journal	Austria	69	1	50.72	-	17-57 (31.23/8.73)
Ibrahim	2012	Dissertation	USA	85	1	92.94	Graduate	21-41 (23.41/-)
Hernández-Torrano, Prieto, Ferrándiz, Bermejo, & Sáinz	2013	Journal	Spain	563	1	53.29	7th-10th	12-16 (14.05/1.06)
Hokanson & Bart	2013	Conference	USA	86	1	-	8th-11th	-
Dziedziewicz, Gajda, & Karwowski	2014	Journal	Poland	122	1	36.07	Primary	8-12
Lew, Lee, Kang, & Park	2014	Journal	South Korea	117	1	47.86	4th	-
Chi, Kim, & Kim	2016	Journal	South Korea	203	1	51	Kindergarten	(5.48/0.28)
Ibrahim, DeMiranda, & Siller	2016	Conference	USA	88	1	-	-	21-41

Table 1 (continued)

Author	Year	Publisher	Country	*N*	No. of matrices	Gender (Male%)	Grade	Age range *(M/SD)*
*Kim, Park, Yoo, & Kim	2016	Journal	South Korea	262	2	46.20	7th	13-14
*Cho	2017	Journal	USA	59	2	59.32	Undergraduate	-
Ferrándiz, Ferrando, Soto, Sáinz, & Prieto	2017	Journal	Spain	260	1	46.50	Primary and secondary	8-15 (10.12/1.57)

Table 2

Estimates of I^2 Index (given in percentage) for the Variability across the Included Studies

	Flu	O	RPC	E	AT
Flu	-				
O	99	-			
RPC	89	88	-		
E	93	83	85	-	
AT	97	82	85	58	-

Note. F = Fluency; O = Originality; RPC = Resistance to premature closure; E = Elaboration; AT = Abstractness of titles.

Table 3

Fit Indices for Structural Models of the Figural TTCT (N = 6,982)

Models	Number of factors	χ^2	df	χ^2/df	CFI	RMSEA	SRMR
Model 1	One	48.55**	5	9.71	.9594	.0353	.0956
Model 2	Two	43.09**	4	10.77	.9636	.0374	.0898
Model 3	Two	11.47**	3	3.82	.9921	.0201	.0424
Model 4	Two	12.04*	4	3.01	.9925	.0170	.0448

Note. CFI = Comparative fit index; RMSEA = Root mean square error of approximation; SRMR = Standardized root mean square residual.

*p < .05. **p < .01.

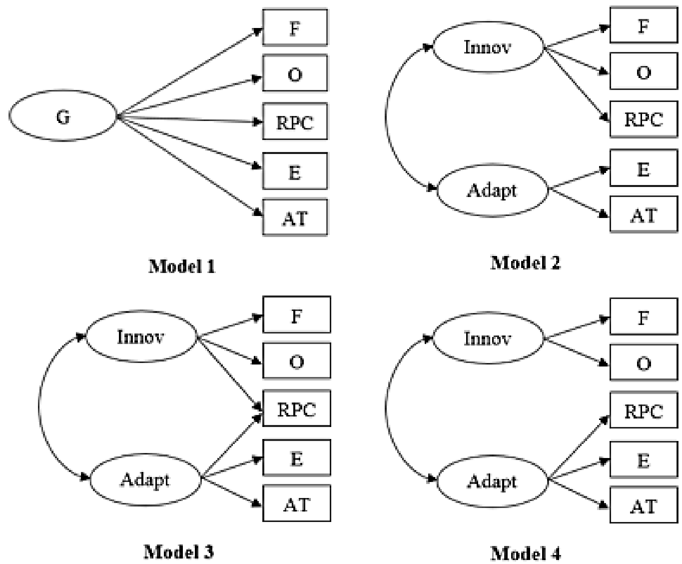

Figure 1. Models of the Figural TTCT tested in this study. *Note*. Innov = Innovative; Adapt = Adaptive; F = Fluency; O = Originality; RPC = Resistance to premature closure; E = Elaboration; AT = Abstractness of titles.

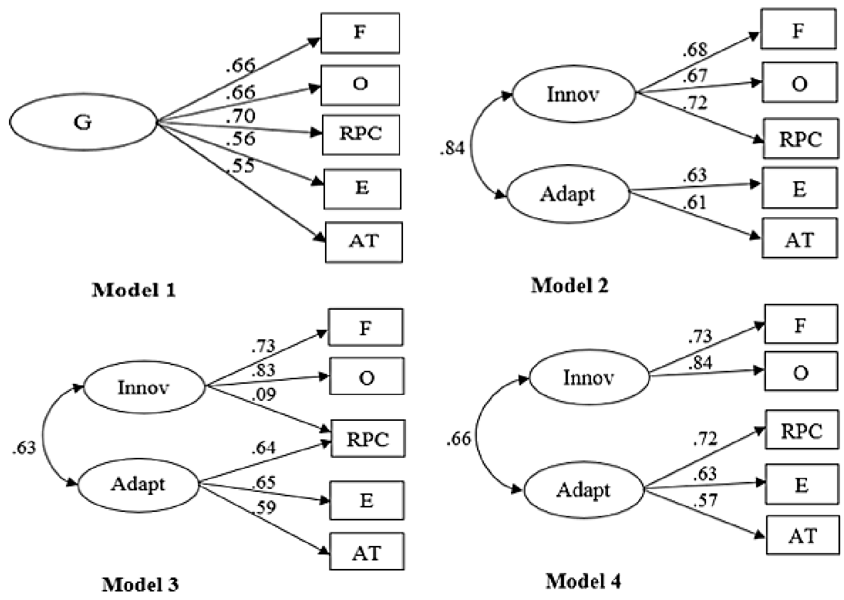

Figure 2. Factor loadings for the Figural TTCT models. *Note*. Innov = Innovative; Adapt = Adaptive; F = Fluency; O = Originality; RPC = Resistance to Premature Closure; E = Elaboration; AT = Abstractness of titles.